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13. ABSTRACT (Maximum 200 words)

Experimental facilities have been designed and built for liquid injection lines in both spherical and cylindrical vessels. Heating equipments including vessel band heaters and liquid line heater along with pressure transducer and thermocouples have been added to cylindrical vessel. Burning speed of JP-8 air mixtures was measured in a range of temperature and pressure. Flame pictures have been taken in the cylindrical vessel with end glasses using a high speed CCD camera. The reults are presented in this report.

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Enclosure 1

Final Progress Report

Autoignition and Burning Speeds of JP-8 Fuel at High Temperatures and Pressures

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1. **M. Matlo, F. Parsinejad and H. Metghalchi, "Schlieren and shadowgraph images of transient expanding spherical thin flames", Proceedings of IMECE2002: ASME International Mechanical Engineering Congress & Exposition, New Orleans, Louisiana, November 2002.**

   F. Rahim, M. Metghalchi, J. Keck, "Development of Reaction Mechanism and Measurement of Burning Speeds of Methane/Oxidizer/Diluent Mixtures at Low Temperatures and High Pressures", Western States Combustion Institute, La Jolla, California, March 2002.

   Farzan Parsinejad and Mohamad Metghalchi, *A Mathematical Model for Schlieren and Shadowgraph Images of Transient Expanding Spherical Thin Flames,* ASME International Journal of Engineering for Gas Turbines and Power, 126-2 (2004), 241-247.

   Sergio Ugarte, Mohamad Metghalchi, James C. Keck, *Methane Oxidation Modeling Using the Rate-Controlled Constrained-Equilibrium Method,* Proceedings of the Fall technical meeting of the US Eastern Section of The Combustion Institute, Penn State, Oct., 2003.

   Sergio Ugarte, Mohamad Metghalchi, James C. Keck, *Methanol Oxidation Induction Times Using the Rate-Controlled Constrained-Equilibrium Method,* Proceedings of IMECE 2003 ASME International Mechanical Engineering Congress and Exposition, Washington D.C., Nov., 2003.

   F. Parsinejad and H. Metghalchi, "Burning Speed Measurement of JP-8 Air Flames", Proceedings of IMECE2004: ASME International Mechanical Engineering Congress & Exposition, Anaheim, California, USA, 2004.

2. **One Manuscript and five Peer Reviewed Papers.**
3. **One Ph.D. student, one Master's student and one Bachelor's degree student.**
4. **No inventions.**
5. **Experimental facilities for heating combustion chamber have been added to the current set up. Data have been collected for liquid fuel (JP-8) and burning speed has been calculated using a thermodynamic model. Also flame pictures have been studied for any cracked or wrinkled flame structure.**
6. **No patents.**
7. **Farzan Parsinejad earning a Ph.D. and Christian Arcari earning a Master's degree.**

Introduction

MIL-T-83133C grade JP-8 is of interest to the U.S. Army as the single fuel for the battlefield. The conversion to JP-8 occurred primarily to improve the safety of aircraft, although the "single fuel for the battlefield" concept (and the similarity of jet fuel to diesel fuel) is centered on the use of aviation kerosene in all Air Force and Army aircraft and ground vehicles. Detailed chemical kinetic mechanisms that describe combustion of many of the components in JP-8 are not available and are unlikely to be developed in the near future. Hence there is a need to study the characteristics of JP-8 experimentally.

The following is the final progress report on our developments and accomplishments through May 2001- May 2004. The detail of the experimental facilities including two combustion chambers, spherical and cylindrical, optical set up, a high temperature oven and also our thermodynamic model used to calculate burning speed were discussed in the last reports and will be briefly discussed here. Measurements have been done in these facilities for gaseous and liquid fuels over the wide range of temperature and pressure. In the last year we developed a new heating system for fuel injection line in cylindrical vessel. The liquid fuel line in the spherical vessel was redesigned. Burning speeds of premixed JP-8 air have been measured for a range of temperature and pressure. Pictures of JP-8 flame have been taken using the high speed CCD camera in the cylindrical chamber. The results are presented in this report.

Experimental Set up

The burning speed measurements were made in the existing spherical combustion chamber. The spherical chamber consists of two hemispheric heads bolted together to make a 15.4 cm inner diameter sphere. The chamber was designed to withstand pressures up to 425 atm and is fitted with ports for spark electrodes, diagnostic probes, and ports for filling and evacuating it. A thermocouple inserted through in one of the chamber ports was used to check the initial temperature of the gas inside the chamber. A Kistler 603B1 piezo-electric pressure transducer with a Kistler 5010B charge amplifier was used to obtain dynamic pressure vs. time records from which the burning speed was determined. Ionization probes mounted flush with the wall located at the top and bottom of the chambers were used to measure the arrival time of the flame at the wall and to check for spherical symmetry and buoyant rise.

The spherical vessel is housed in an oven which can be heated up to 500 K. Liquid fuel is stored in a 115 cc heated pressure vessel and is transferred through a heated line inside the oven to the spherical chamber. Several thermocouples are located on the line from the fuel reservoir to the vessel to monitor temperature of the fuel passageway. A heated strain gauge (Kulite XTE-190) in the oven is used to measure partial pressure of fuel in the vessel.

The companion cylindrical chamber is made of SAE4140 steel with an inner diameter and length of 133.35 mm. The two end windows are 34.93 mm thick Pyrex with a high durability against pressure and temperature shocks as well as having very good optical properties. A Z-type Schlieren/Shadowgraph ensemble has been set up to visualize the flame propagation. A high speed CCD camera (1108-0014, Redlake Inc.) with a capture rate of up to 8000 frames per second is placed very close to the focal point of the second mirror. Two band heaters and a rope heater wrapped around the cylindrical vessel are used to heat up the inside temperature of the vessel up to 500 K. This chamber is equipped with a heated liquid fuel line system, a pressure strain gauge and thermocouples similar to the spherical vessel. The oven was omitted to permit flame observation for this application.

The gas handling system used with these facilities consists of a vacuum pump for evacuating the system and a valve manifold connected to gas cylinders for preparation of the fuel/oxidizer/diluent mixtures. Partial pressures of the fuel mixtures were measured using Kulite strain gauge pressure transducers in the 0-15 atm range. Two spark plugs with extended electrodes were used to ignite the mixture at the desired location in the chambers. An electronic ignition system controlled by the data acquisition program provides a spark with the necessary energy. The data acquisition program synchronizes the ignition with the dynamic pressure recording and Schlieren/Shadowgraph photography.

The data acquisition system consists of a Data Translations 16 bit data acquisition card, which records the pressure change of the combustion event at a rate of 250 kHz. The analog to digital converter card receives the pressure signal from the charge amplifier and the signals from the ionization probes. All signals are recorded by a personal computer and an output data file is automatically generated. The output data files include the dynamic pressure and its corresponding time.

The test procedure begins by evacuating the vessel and gas handling system using the vacuum pump. The chamber then is filled with JP-8 vapor to the desired pressure and air is added. The vessel and the fuel tank are at the same temperature during the filling. After the chamber is filled with the proper mixture, several minutes are allowed for the system to become quiescent before it is ignited. This will prevent any turbulence inside the vessel. Six thermocouples on the liquid line are used to make sure that temperature along the filling line is never below the condensation temperature for JP-8. At least three runs at each initial condition were made to provide a good statistical sample. Based on statistical analysis, it was found that three runs are sufficient to achieve a 95% confidence level. Figure 1 shows the schematic of two combustion chambers.

Figure 2 shows a schematic of the liquid fuel line and the cylindrical vessel. The liquid fuel line system is equipped with Kulite XTE-190 pressure strain gauge and thermocouples similar to the spherical vessel. A 50 cc open liquid fuel reservoir is connected to the vertical liquid line 15 cm above the table. Two valves are controlling the liquid flow rate. The line forms a coil around a 7 cm diameter tube which is heated up to 500 K. This allows the liquid fuel to vaporize as it slowly moves through the coil. The partial pressure of the fuel is monitored by the pressure gauge as it slowly occupies the system. Figure 3 shows the fuel reservoir and heated coil on the line.

Theoretical Model

The theoretical model used to calculate burning speed from the pressure rise in a constant volume chamber is based on one previously developed by Metghalchi and Keck and Rahim et al with some modifications. The burning velocity is calculated by the equation:

$$S_u = m\, v_u \dot{x} / A_f \tag{1}$$

Where:

S_u : Burning velocity

m : Mass of the gas mixture in the chamber

v_u : Specific volume of the unburned gas

$\dot{x}$: Mass fraction burning rate

A_f : Flame area

Using the volume and energy equations, temperature and mass fraction of burned gas are determined iteratively:

$$\frac{V}{m} = \int_0^x v_b dx'' + \int_x^{x'} v_{u_s} dx'' + \int_{x'}^1 v_{b.l.} dx'' \tag{2}$$

$$\frac{E}{m} - \frac{Q}{m} = \int_0^x e_b dx'' + \int_x^{x'} e_{u_s} dx'' + \int_{x'}^1 e_{b.l.} dx'' \tag{3}$$

Where:

e : Specific internal energy.

E : Total initial energy of gas in the chamber.

Q : Energy transfer via heat interaction from boundary layer to the vessel and radiation from burned gas to the wall.

x : Mass fraction burned.

x' : Total mass fraction of gases outside the boundary layer

x'' : Integration variable.

v : Specific volume.

V : Combustion chamber volume.

The subscripts *b* and *u* refer to the burned and unburned gas respectively and subscript *b.l.* and *s* refer to boundary layer and isentropic process.

Experimental Results

1. Gaseous Fuel, methane-air-diluent mixtures:

Measurements have been done for methane-air-diluent (Extra diluent consisting of CO_2 and N_2 will be added to simulate the conditions in an engine) over the pressure range of 1-20 atm and temperature range of 298-650 K for equivalence ratios of 0.8-1.2. In the approach taken here, the pressure is the primary measurement. A thermodynamic analysis of the pressure time record that was used to calculate laminar burning speeds has been presented in the previous report. The measured values were compared to PREMIX code's theoretical predictions using GRI-Mech 3.0 mechanism. As it was expected, the agreement is very good at high temperature, low pressure condition. GRI-Mech 3.0 predicts higher values at high pressure, low temperature conditions.

Investigation of cracking or wrinkling has been done in the cylindrical chamber. In order to observe at what pressure the flame starts to become cellular, flames have been visualized in the cylindrical chamber. The burned gas volume and pressure relation has been plotted in Figure 4 for different mixtures. It can be seen that the effect of equivalence ratio, diluent percentage and initial pressure is very small on the behavior of this curve. The final pressure achieved in the combustion chamber is different for different mixtures.

Shadowgraph photographs of flame propagation for stoichiometric methane-air-diluent mixtures with initial pressures of 1 atm and diluent of 0-15% (p_i = 1 atm, T_i = 298 K) are shown in Figure 5. Inside the cylindrical vessel, the pressure reaches approximately 5 times its initial value before the flame hits the wall. It can be seen that throughout the whole experiments, the flame is smooth and spherical for all these mixtures.

The burning speeds along isentropes for stoichiometric methane-air-diluent mixtures with initial pressures of 1 atm and diluent of 0-15% are shown in Figure 6. The agreement between measured values and PREMIX calculations are good. Also in this figure, the power law fits to the experimental data have been shown along with the actual data. It can be seen that adding diluent decreases the burning speed and the final pressure achieved in the vessel becomes smaller. Mixtures with more diluent have lower flame temperature and consequently lower flame speed. In mixtures with high percentage of diluent, buoyancy can be significant. This can be detected using the ionization probes signals. In Figure 6 all the measured values are for smooth flames, therefore the measured values are the laminar burning speeds.

At high pressures, the flame front is cellular and instabilities can be observed even at smaller radii, as shown in Figure 7a. Shadowgraph photographs of flame propagation for stoichiometric methane-air-diluent mixtures with initial pressures of 5 atm and diluent of 0-15% (p_i = 5 atm, T_i = 298 K) are shown in Figure 7. Cellularities can be seen in methane-air mixture with no diluent at pressures around 7-8 atmosphere. By adding diluent to the mixture, part b-d of the figure, although the flames are still cracked, but they do not develop to any cellular structure. By adding diluent up to 15%, cracks become less but the effect of buoyancy can be observed.

Figure 8 shows the burning speed of stoichiometric methane-air-diluent mixture with initial temperature of 298 K, initial pressure of 5 atmospheres and diluent range of 0-15%. Again as we increase the amount of diluent the burning speed decreases. It can be observed that the agreement between measured values and PREMIX is good for mixtures with 5% diluent and higher. For methane-air mixture with no extra diluent, the measured values are higher than PREMIX. This again can be due to the instabilities in flame structure that increases the burning rate and consequently the measured values are higher than laminar burning speeds calculated by PREMIX. This has been verified in Figure 7a. As it has been discussed in the previous section, the flame becomes cellular for stoichiometric methane-air mixtures with initial pressure of 5 atm, at pressures around 7-8 atm.

In Figure 9, the lean methane-air mixture is at higher pressure (p_i = 5 atm, ϕ = 0.8). It can be seen in Figure 9a that at a pressure ratio (p/ p_i) of 1.26, cells start to grow on the flame surface. This might be the reason for the higher measured values than PREMIX calculations in Figure 10. The burning speeds of cellular flames are shown by hollow symbols in Figure 10. The effect of diluent on the measured and calculated burning speeds along isentropes for methane-air-diluent at an equivalence ratio of ϕ = 0.8, initial temperature of 298 K and initial pressure of 5 atmosphere has been shown in Figure 10. Adding diluent reduces the burned gas temperature making the flame slower and moving it into the low temperature/high pressure regime. As can be seen, the agreement between calculations and experimental results is poor. In the case of 0 and 5% diluent the measured values cross the PREMIX predictions. As the amount of diluent is increased to 10 and 15%, PREMIX predicts higher values. In order to explain this, more studies of flame structure are required. In Figure 9b-d, flame propagation of methane-air-diluent mixtures (p_i = 5 atm, T_i = 298 K) with 5, 10 and 15% diluent respectively, are shown. Instabilities can be observed around a pressure ratio of 1.6 in 9b. This could be again the explanation for the higher measured values than PREMIX predictions for this mixture at around the same pressure. For a methane-air mixture with 10 and 15% diluent, the flame is stable due to excess nitrogen, which suppresses instabilities. Measurements have been made only up to the point that flame hits the top wall. Ionization probes mounted flush with the wall at the top and bottom of the chambers are used to measure the arrival time of the flame at the wall and check for spherical symmetry and buoyant rise. Adding diluent makes the flame slower and consequently the flame is buoyant and in the some cases is also distorted.

Shadowgraph photographs of flame propagation for rich methane-air-diluent mixtures with initial pressures of 5 atm and diluent of 0-10% (p_i = 5 atm, T_i = 298 K and ϕ = 1.2) are shown in Figure 11. The flames are smooth for all the mixtures with different amount of diluent. In Figure 12, burning speeds of same methane-air-diluent mixtures at an equivalence ratio of ϕ = 1.2 are shown. As is shown in this figure, PREMIX over-predicts for mixtures with 0, 5 and 10% diluent. As can be seen in Figure 12, the measured burning speeds at high pressures for rich methane-air mixture are lower than PREMIX predictions. Considering Figure 11, it can be concluded that for stable flames at high pressures, measured flame speeds are lower than PREMIX predictions. Other investigators have also seen disagreement between measured burning speeds and calculations using GRI-Mech 3.0 model at high pressures. For unstable flames at high pressures, the measured values are higher than PREMIX because of higher speed of cellular flames.

Mixtures of gaseous and liquid fuel with air have been burned in the cylindrical vessel with new heating facility to experiment at higher initial temperatures. Flame pictures have been taken using the Schlieren/Shadowgraph set up and high speed CCD camera.

Figure 13 presents the flame propagation of stoichiometric propane air mixture at initial temperature and pressure of 450 K and 1 atm, respectively. The pressure and temperature at the end of combustion when flame hits the wall are about 7 atm and 650

K, respectively. Each picture is taken 3 ms after the previous one. As it is shown in the pictures, the flame is smooth and not buoyant till it hits the wall. This supports our assumption in burning speed measurements.

2. Liquid Fuel, JP8-air mixtures:

Flame pictures of Ethanol and air mixture are shown in Figure 14. The mixture is stoichiometric and initial temperature is 298 K. Initial pressure is 1 atm. All pictures are shown with 3 ms time difference from their previous one. Ethanol is liquid in room temperature. However, its vapor pressure at room temperature is enough to make a stoichiometric mixture. Figure 14 shows that the flame is smooth and there is no instability till it quenches at the wall. Again there is no sign of buoyancy on the flame. The final pressure and temperature reach to about 6 atm and 450 K.

- **Burning Speed of JP-8**

Burning speeds of JP-8 air mixtures at wide range of temperature, pressure and stoichiometric ratio has been measure using the spherical vessel and pressure method.

Figure 15 shows the flame propagation of stoichiometric JP-8 and air mixture at initial temperature and pressure of 450 K and 1 atm, respectively. Each picture shown is taken 3 ms after its previous one. Flame propagates smoothly almost all the vessel. Instability starts at pressure of 5 atm and temperature of 650 K. This instability shows itself as cracks on the flame surface which turns into cellular form as pressure and temperature rise. Again there is no buoyancy on the flame. This Figure suggests that for higher pressures flame is likely to be cellular and not laminar.

Burning speed measurements have been made in the spherical chamber using the same thermodynamic model for JP8-air mixtures. In Figure 16, the pressure-time history of stoichiometric JP8-air mixtures with initial temperature of 500 K and initial pressure of 1 atmosphere. Ionization signals are also shown in this figure. The signals verify that for this particular flame there is no buoyancy effect and flame is symmetrical.

By increasing the initial pressure to two and five atmospheres, flame becomes slower and also slightly buoyant. The ionization signals show about 2 ms discrepancies in

Figures 17 and 18. Burning speed calculations have been done only up to the point that flame hits the wall at the top.

The burning speeds vs. unburned gas temperatures calculated from the pressure records in Figures 16-18 are shown in Figure 19. The burning speeds are shown along the isentrope and it should be remembered that the pressure is increasing along each isentrope. It can be also observed that by increasing the initial pressure, the burning speed decreases. Some important results are presented in the following.

- Equivalence Ratio

The effect of equivalence ratio on burning speed can be seen in Figures 20-22. Figure 20 shows burning speed measurements for mixtures of JP-8 and air at initial temperature of 450 K and initial pressure of 1 atm with different stoichiometric ratios. Note that results are plotted along the isentropes. That means the pressure values have an isentropic relation with the unburned gas temperature.

Figure 21 and 22 present the same measurements as in Figure 18 for initial pressure of 5 atm and 9 atm respectively.

- Pressure Effect

The effect of pressure on burning speed can be seen in Figure 23. In this Figure burning speeds for stoichiometric mixtures of JP-8 and air at initial temperature of 450 K and various initial pressures have been plotted. It clearly shows that burning speed has an inverse relation with pressure.

- **Autoignition of JP-8**

In Figure 24, the pressure-time history of stoichiometric JP8-air mixtures with initial temperature of 450 K and initial pressure of 1 atmosphere. Ionization signals are also shown in this figure. The signals verify that for this particular flame there is no buoyancy effect and flame is symmetrical. However increasing the initial pressure makes the flame speed slower and also makes the flame buoyant.

As temperature and pressure of unburned gas increase it reaches to a point that all end gas autoignites. An example of this condition is shown in Figure 25. It can be seen that autoignition produces the characteristic violent pressures oscillations associated with “knock” in IC engines. In general we detect the starting point of autoignition by observing the sudden pressure rise in the pressure-time history. For example as is shown in Figure 25, autoignition happens for a stoichiometric JP-8 air mixture at initial temperature and pressure of 500 K and 10 atm respectively where the pressure and temperature reach 36 atm and 680 K.

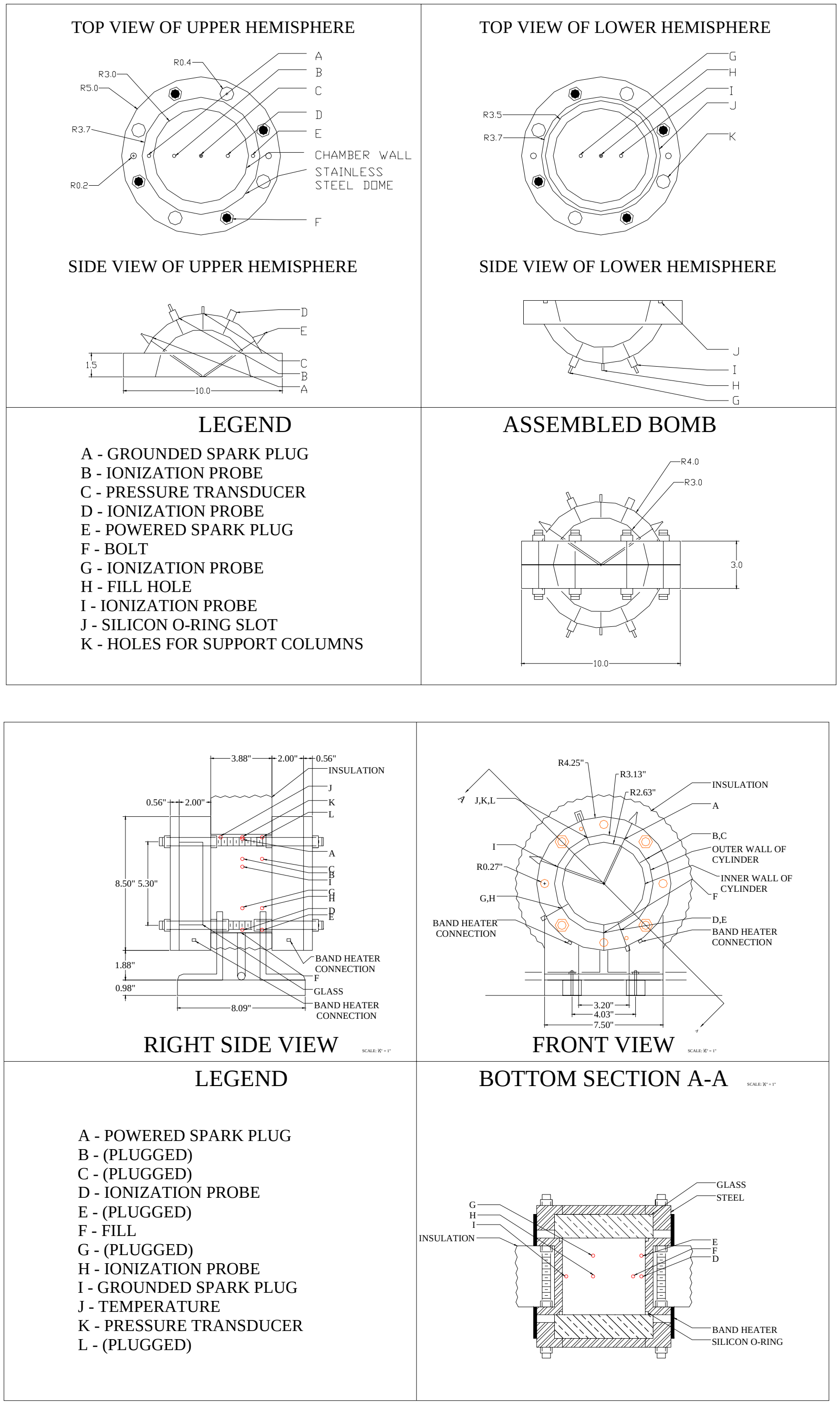


Figure 1a. (top) Schematic of 15.24 cm (6 inch) ID spherical combustion chamber and **1b.** (bottom) 13.33 cm (5.25 inch) ID cylindrical combustion chamber, with aspect ratio of 1.

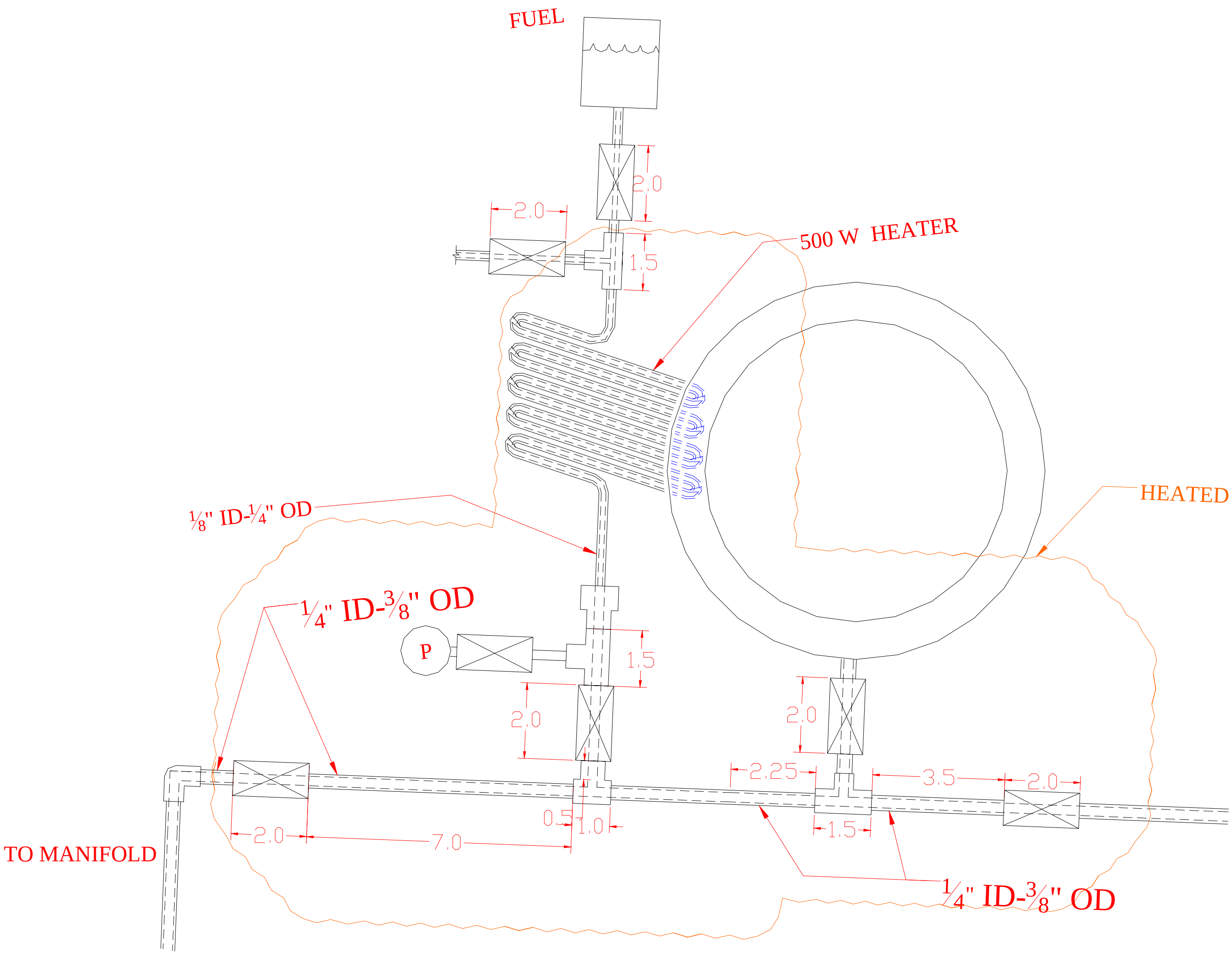


Figure 2: Schematic of the liquid fuel line and the cylindrical vessel.

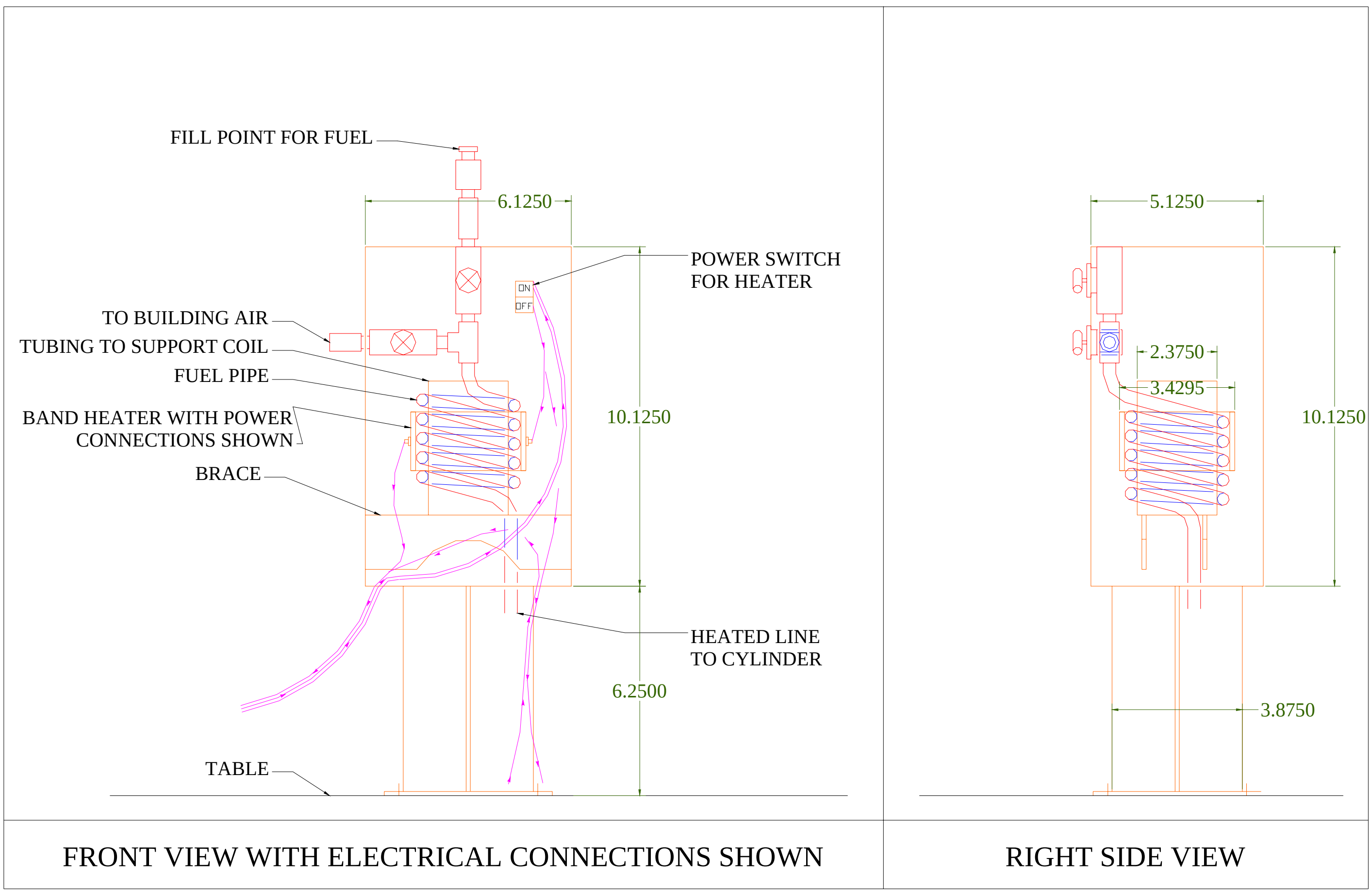


Figure 3: Fuel reservoir and heated coil on the line.

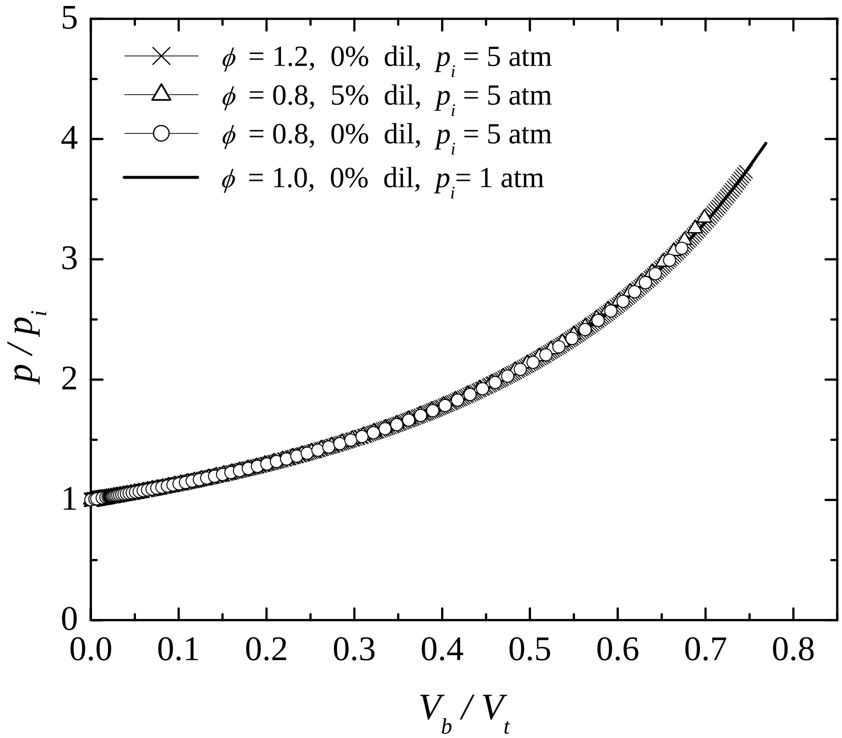
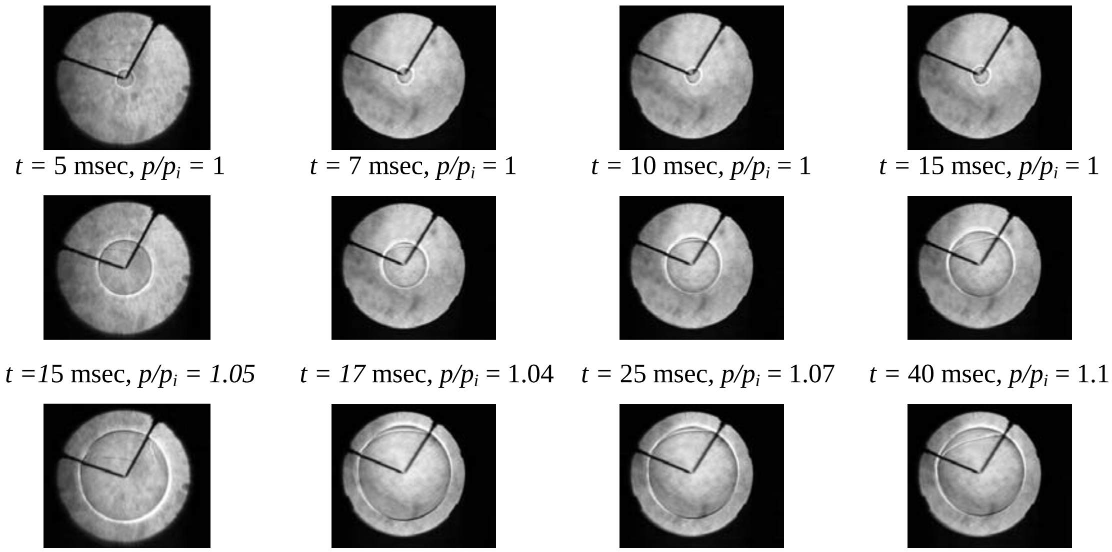


Figure 4- Pressure ratio vs. ratio of burned gas volume to the total volume of combustion chamber for different mixtures of methane-air-diluent mixtures.

ϕ = *1.0*, P_i = *1 atm*,

(a) Dil =0% *(b) 5%* *(c) 10%* *(d) 15%*



t =25 msec, p/p_i =*1.45* t = *30* msec, p/p_i = 1.47 t = 40 msec, p/p_i = 1.5 t = 53 msec, p/p_i = 1.29

Figure 5- Flame propagation in cylindrical vessel, methane-air-diluent mixture, ϕ =1.0, p_i =1.0 atm and T_i = 298 K. (a) 0% diluent (b) 5% diluent (c) 10% diluent (d) 15% diluent.

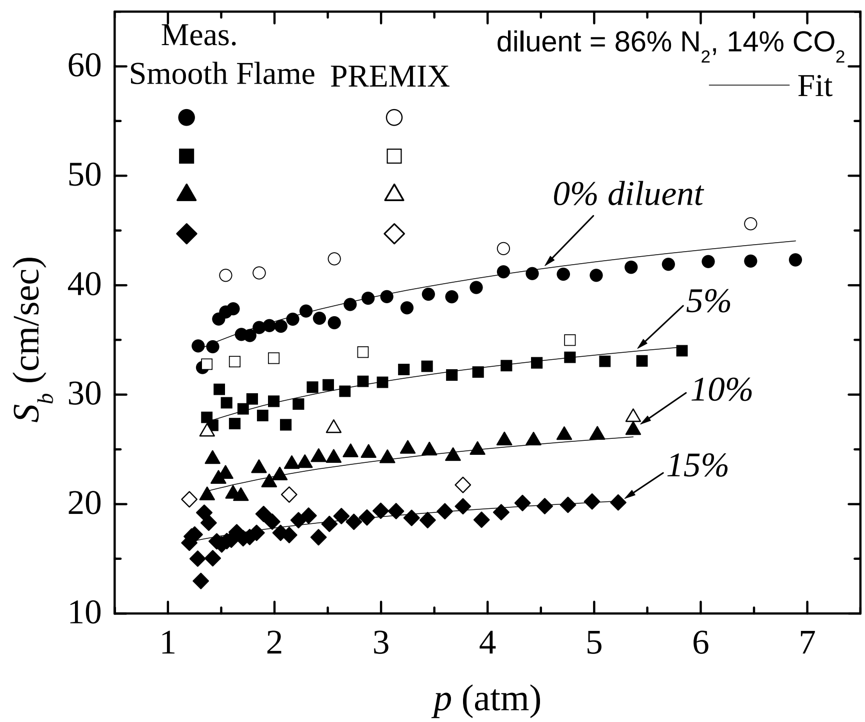


Figure 6- Comparison of burning speed of stoichiometric methane-air-diluent mixtures with those determined by PREMIX code along isentropes with initial pressure of 1 atm and initial temperature of 298 K, with different diluent percentage.

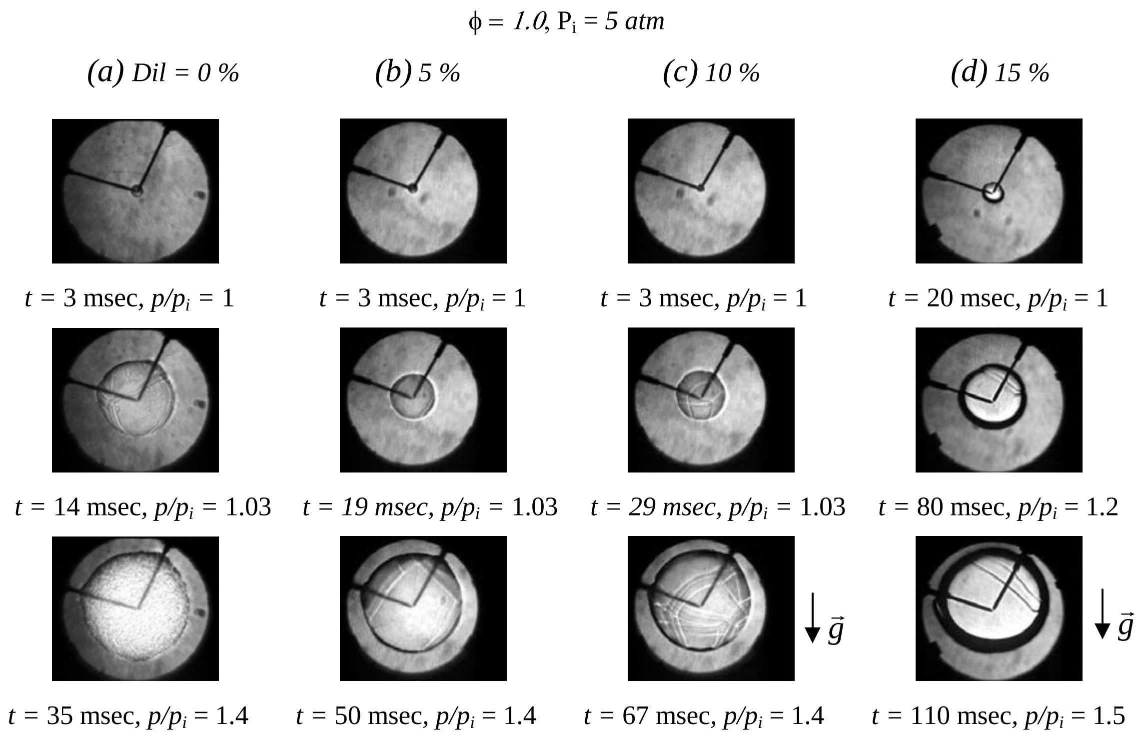


Figure 7- Shadowgraph pictures of flame propagation in the cylindrical chamber. Methane-air-diluent, $\phi = 1.0$, $p_i = 5.0$ atm and $T_i = 298$ K. (a) 0% diluent (b) 5% (c) 10% (d) 15%.

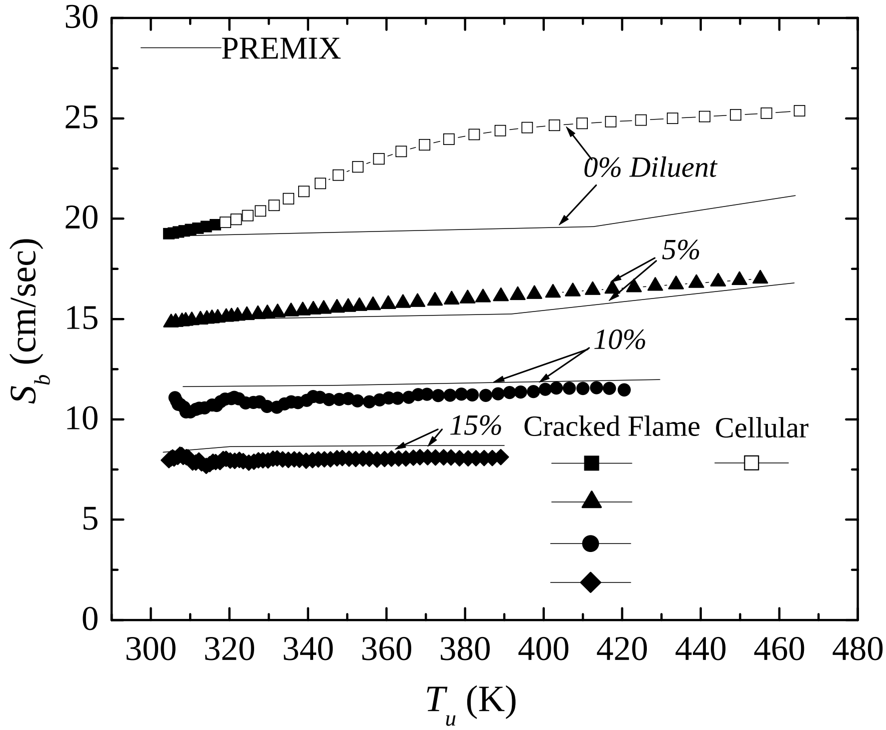


Figure 8- Comparison of burning speed of stoichiometric methane-air-diluent mixtures with those determined by PREMIX code along isentropes with initial pressure of 5 atm and initial temperature of 298 K, with different diluent percentage.

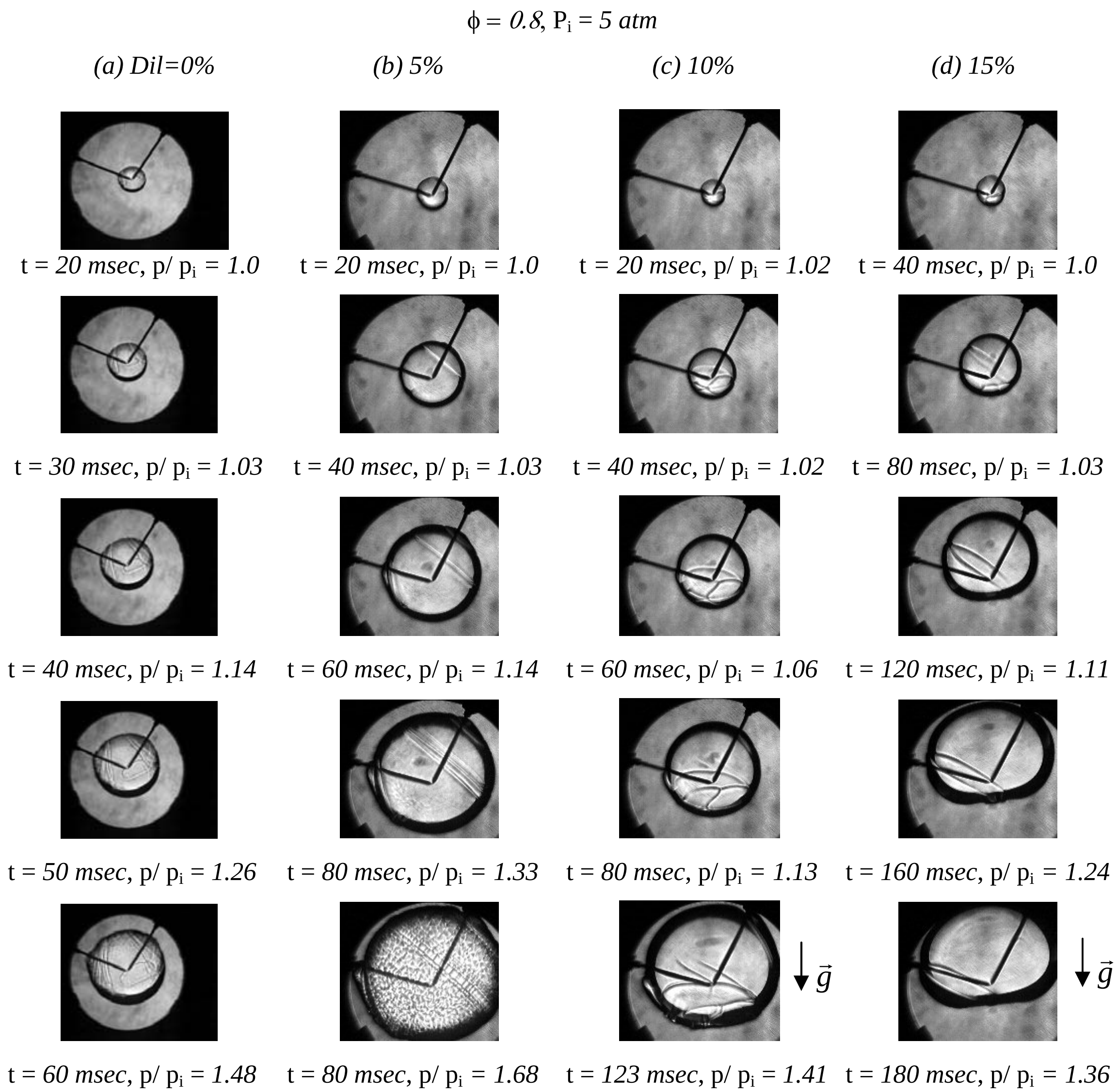


Figure 9- Shadowgraph pictures of flame propagation in the cylindrical chamber. Methane-air-diluent mixture with ϕ =0.8, p_i =5.0 atm and T_i = 298 K. (a) 0% diluent (b) 5% (c) 10% (d) 15%.

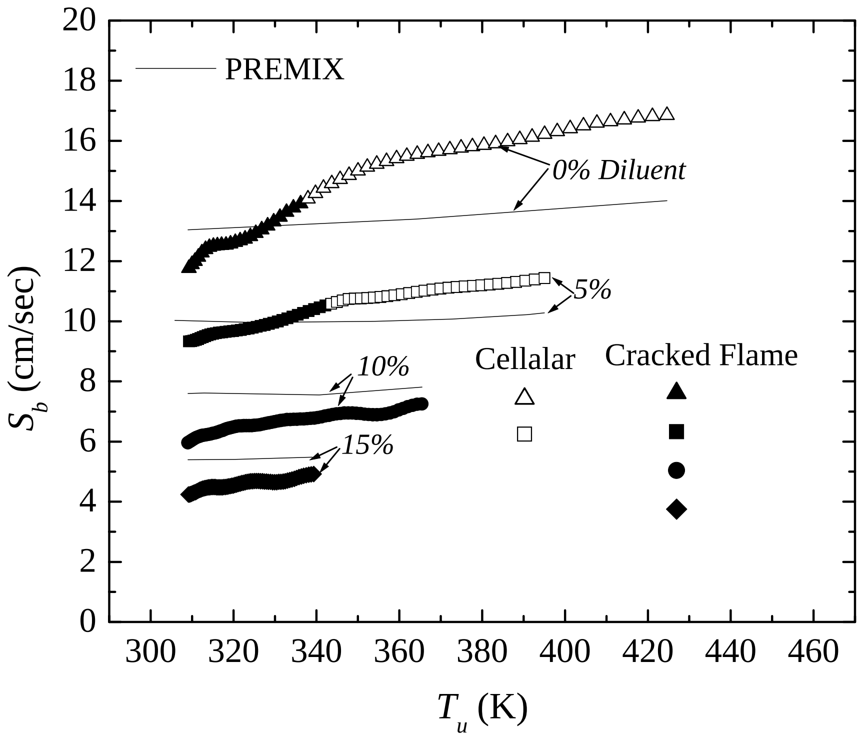


Figure 10- Comparison of burning speed of methane-air-diluent mixtures, $\phi = 0.8$, with those determined by PREMIX code along isentropes with initial pressure of 5 atm and initial temperature of 298 K, with different diluent percentage.

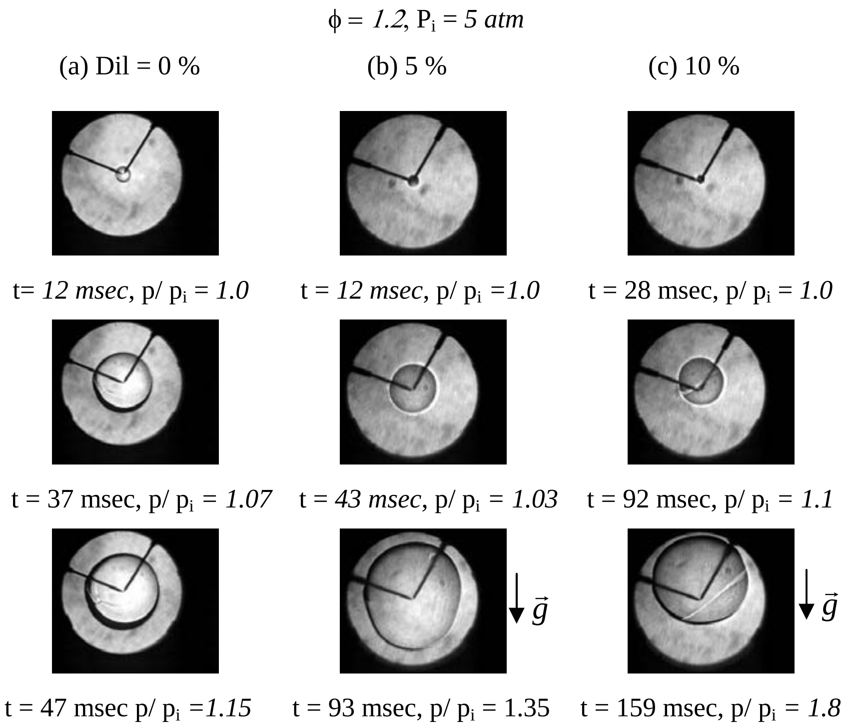


Figure 11- Shadowgraph pictures of flame propagation in the cylindrical chamber. Methane-air-diluent mixture, ϕ =1.2, p_i =5.0 atm and T_i = 298 K (a) 0% diluent (b) 5% (c) 10%.

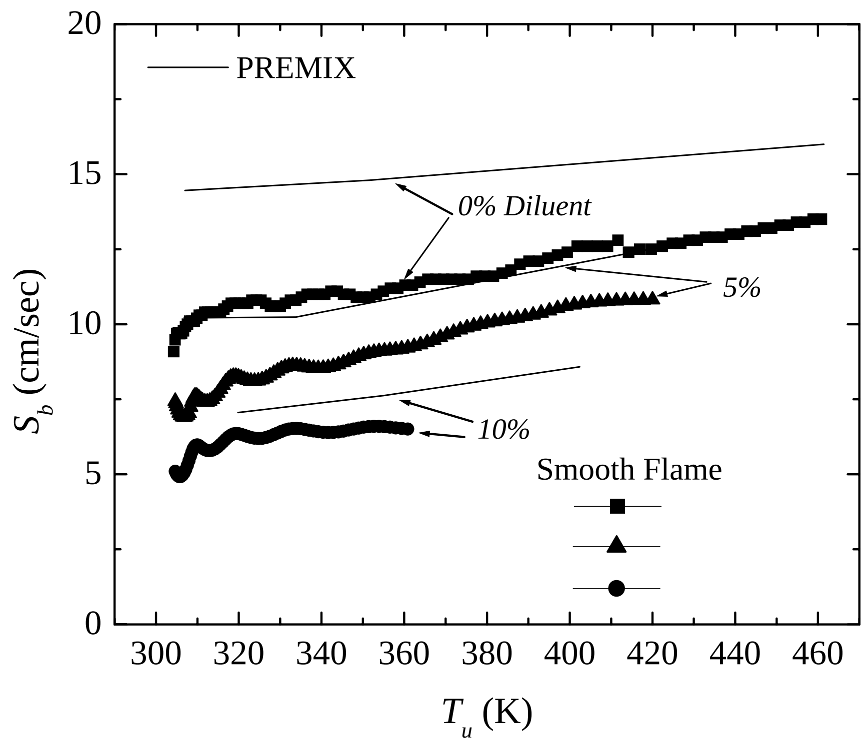


Figure 12- Comparison of burning speed of methane-air-diluent mixtures, ϕ = 1.2, with those determined by PREMIX code along isentropes with initial pressure of 5 atm and initial temperature of 298 K, with different diluent percentage.

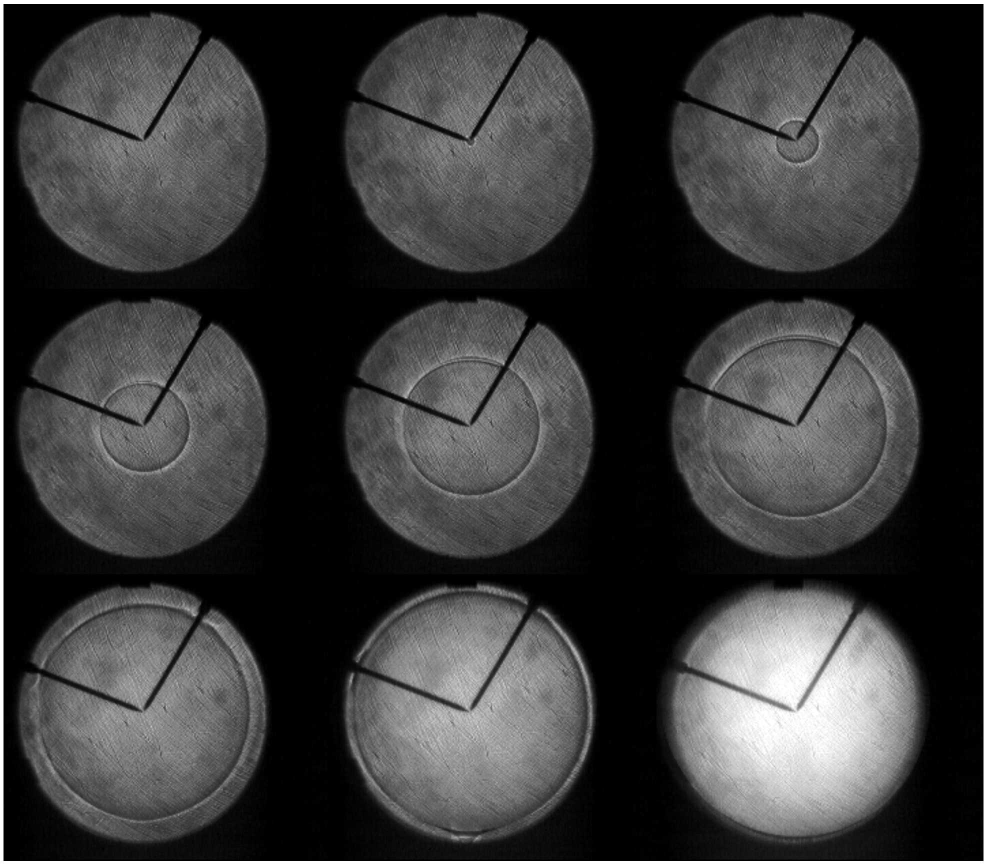


Figure 13: Flame pictures of stoichiometric propane air mixture at initial temperature and pressure of 450 K and 1 atm.

Figure 14: Flame pictures of stoichiometric Ethyl Alcohol and air mixture at initial temperature is 298 K and initial pressure of 1 atm.

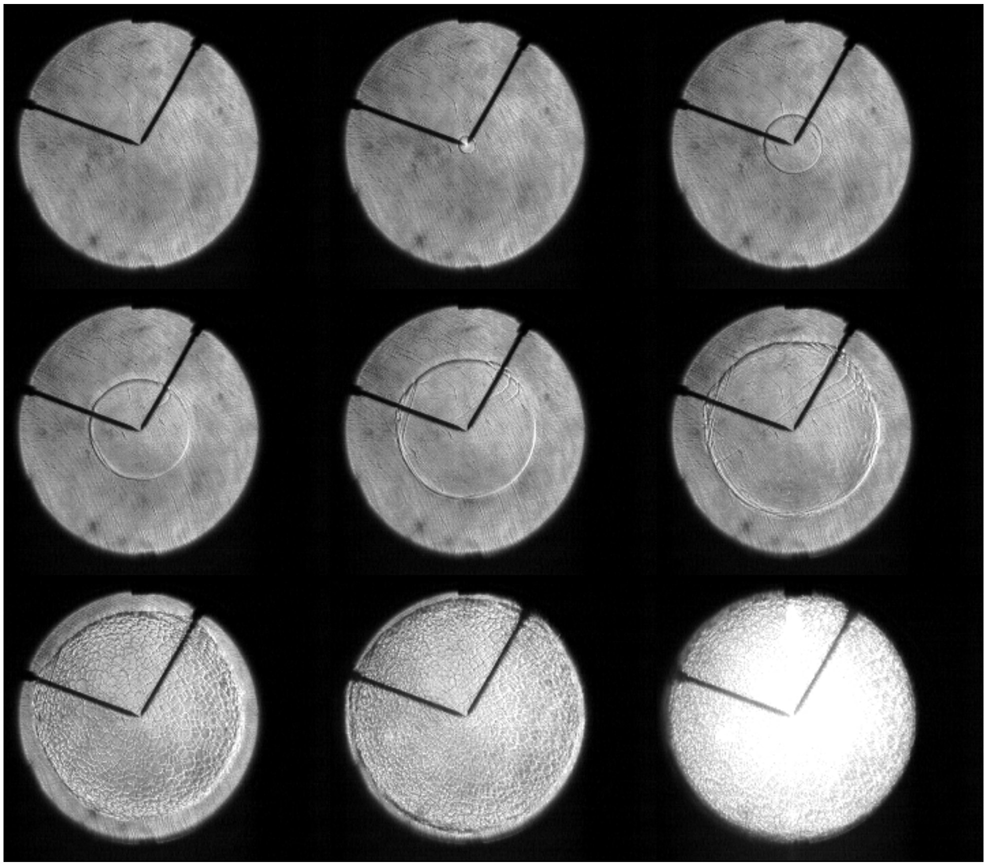


Figure 15: Flame propagation of stoichiometric JP-8 and air mixture at initial temperature and pressure of 450 K and 1 atm.

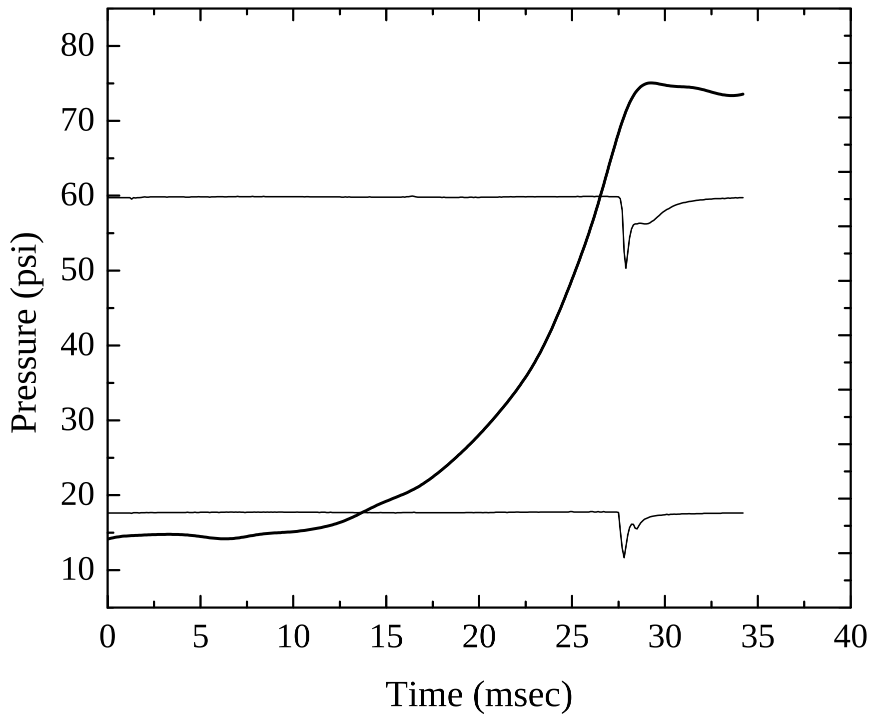


Figure 16- Pressure variation in a constant volume chamber for normal combustion without autoignition. JP8-Air, P_i = 1 atm, T_i = 500 K, ϕ =1.

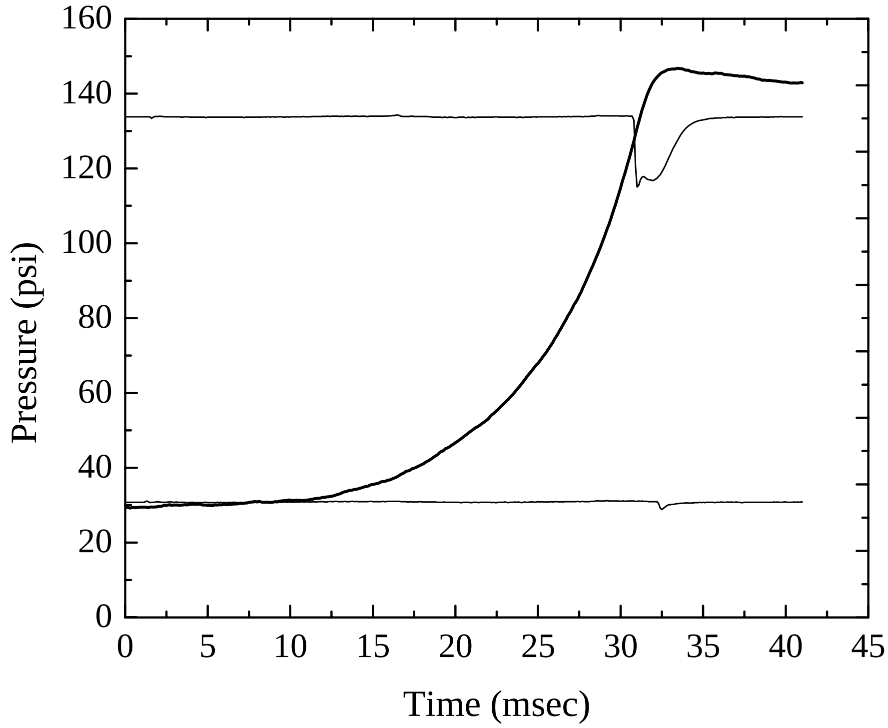


Figure 17- Pressure variation in a constant volume chamber for normal combustion without autoignition. JP8-Air, P_i = 2 atm, T_i = 500 K, ϕ =1.

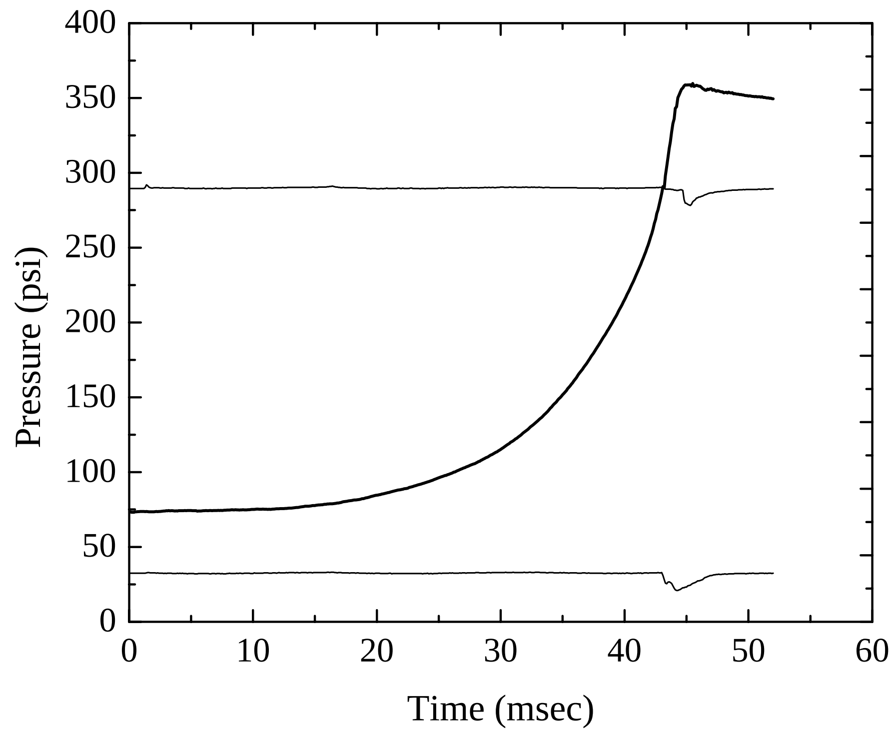


Figure 18- Pressure variation in a constant volume chamber for normal combustion without autoignition. JP8-Air, P_i = 5 atm, T_i = 500 K, ϕ =1.

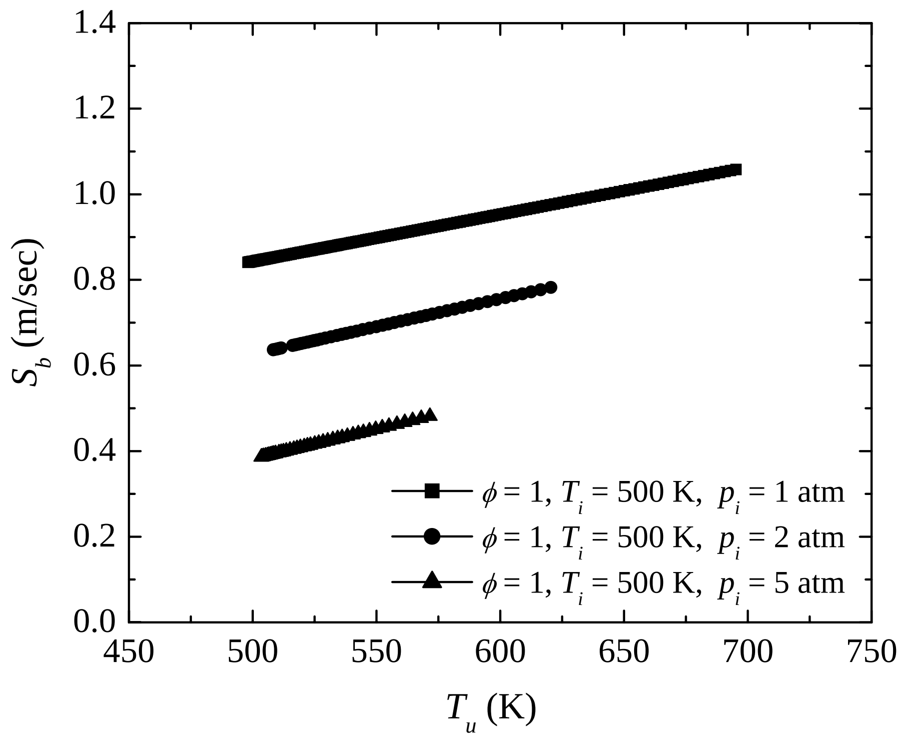


Figure 19- Comparison of burning speed of JP8-air mixtures, ϕ = 1.0, along isentropes with initial pressure of 1, 2 and 5 atmospheres and initial temperature of 500 K.

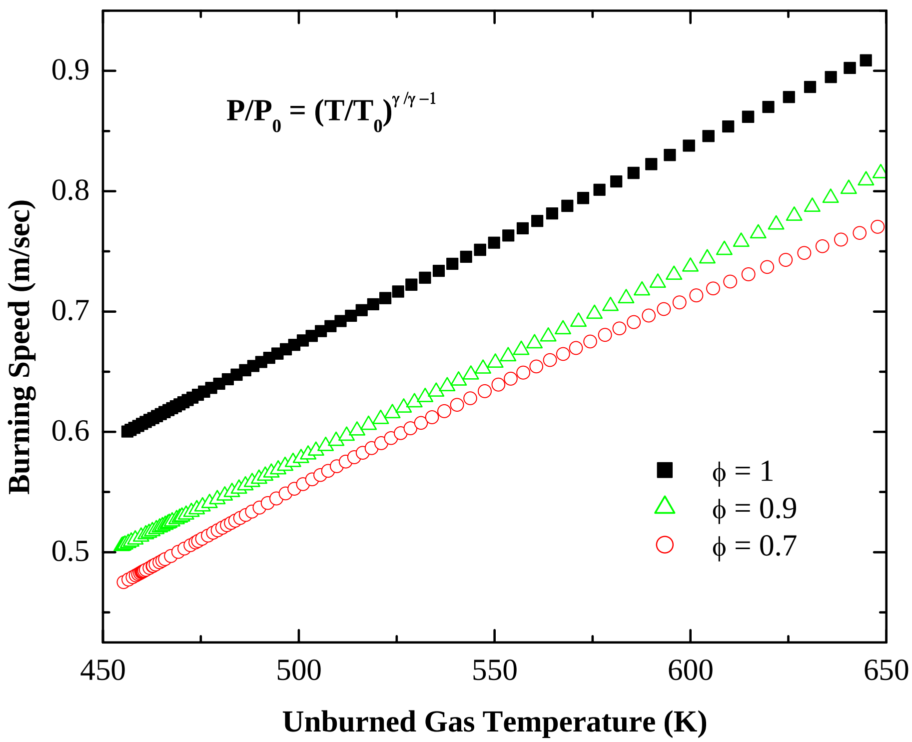


Figure 20: Burning speed measurements for mixtures of JP-8 and air at initial temperature of 450 K and initial pressure of 1 atm

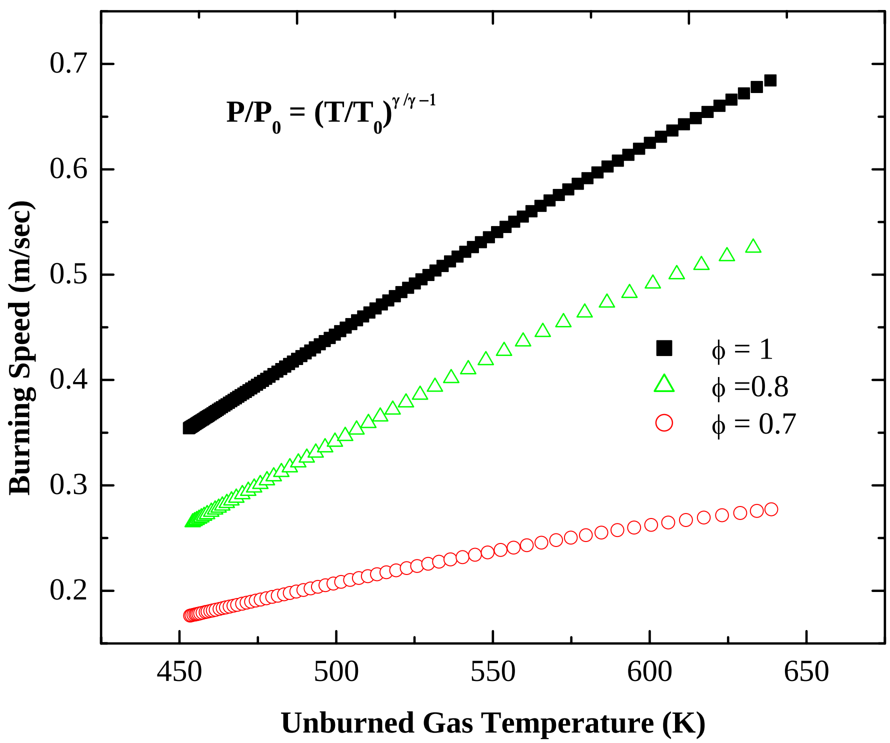


Figure 21: Burning speed measurements for mixtures of JP-8 and air at initial temperature of 450 K and initial pressure of 5 atm

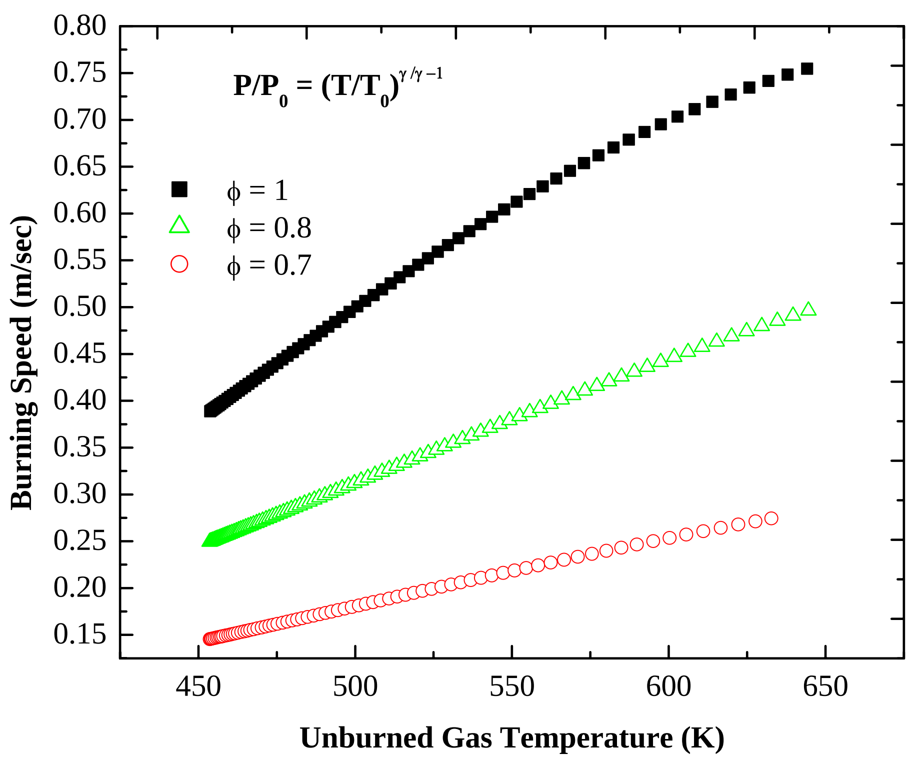


Figure 22: Burning speed measurements for mixtures of JP-8 and air at initial temperature of 450 K and initial pressure of 9 atm

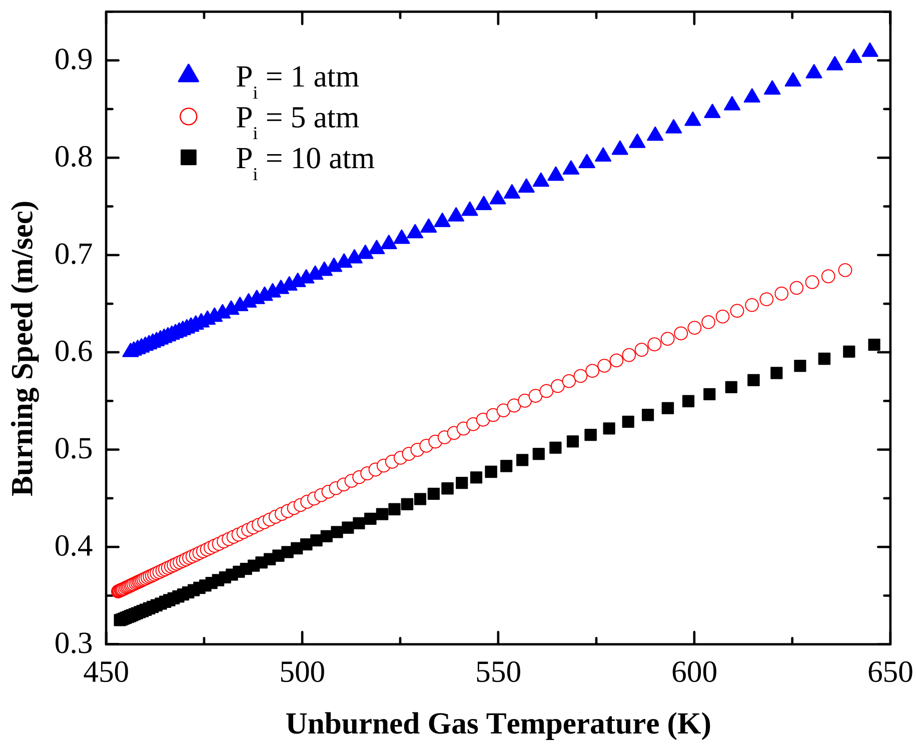


Figure 23: Burning speed measurements for stoichiometric mixtures of JP-8 and air at initial temperature of 450 K.

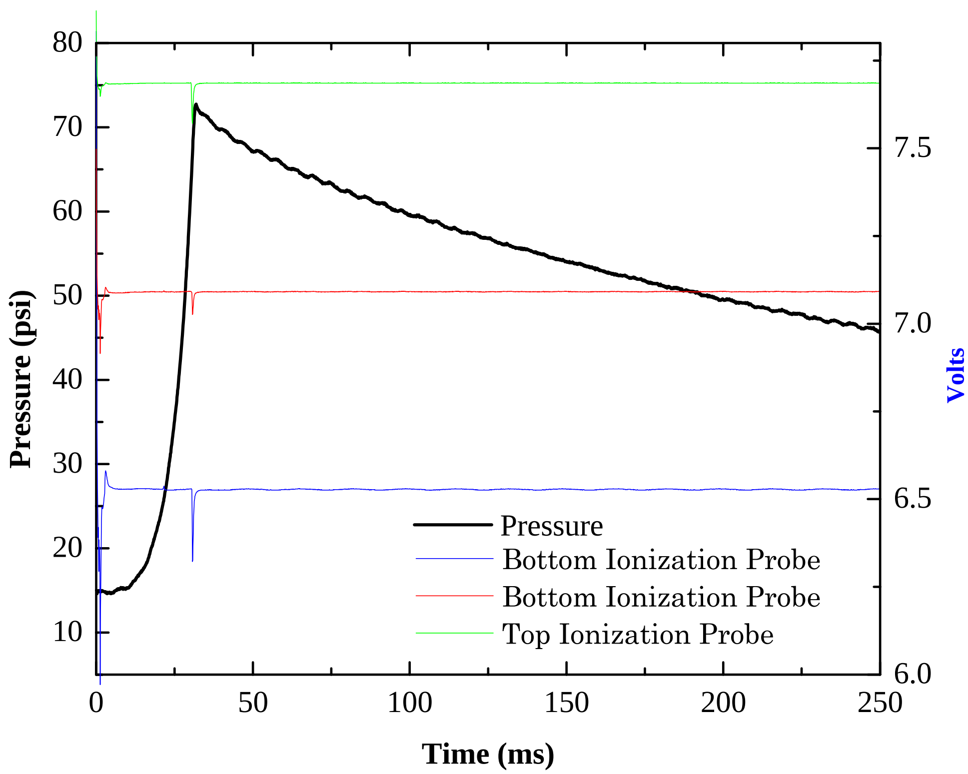


Figure 24: Pressure variation in a constant volume chamber for normal combustion without autoignition. JP8-Air, P_i = 1 atm, T_i = 450 K, ϕ =1.

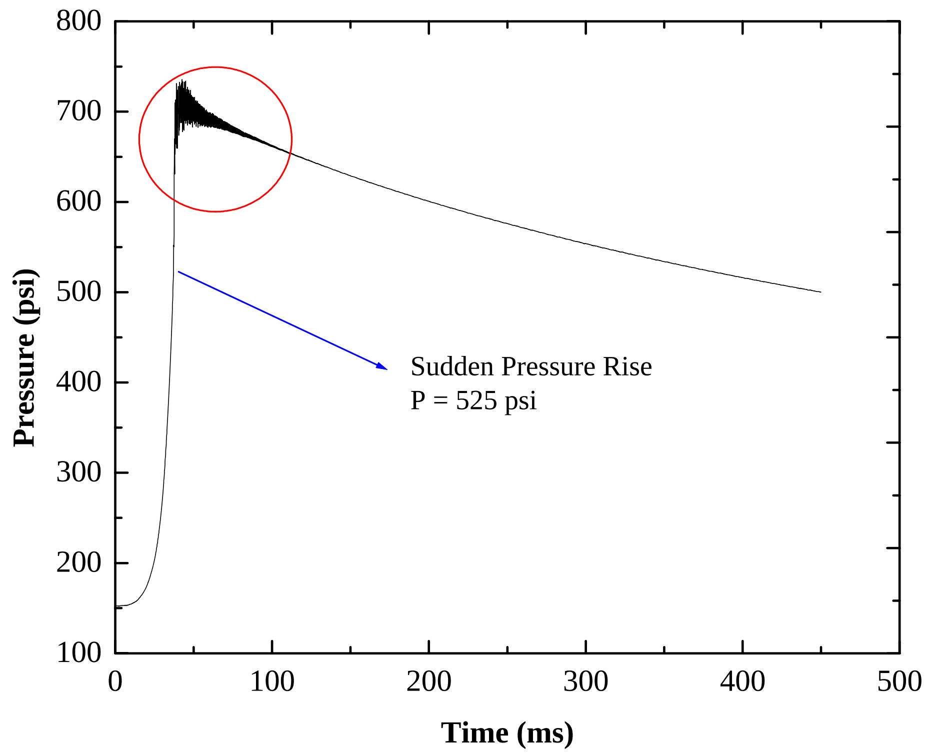


Figure 25: Pressure variation in a constant volume chamber for combustion with autoignition. JP8-Air, P_i = 10 atm, T_i = 500 K, ϕ =1.

Biographical Sketch

NAME: Mohamad (Hameed) Metghaclchi
POSITION TITLE: Professor, Mechanical and Industrial Engineering Department Chair

Research and Professional Experience:

Mohamad (Hameed) Metghalchi received his Bachelor of Science in Mechanical Engineering from Oklahoma University in 1975. He received Masters and Doctor of Science Degree in Mechanical Engineering from Massachusetts Institute of Technology in 1977 and 1980 respectively. In fall of 1979, he joined department of Mechanical Engineering at Northeastern University. Professor Metghalchi is Chair of Mechanical and Industrial Engineering Department.

Professor Metghalchi is an active member of national societies, such as, the American Society of Mechanical Engineers, the American Society of Engineering Education, the Society of Automotive Engineers and the Combustion Institute. He is a Fellow of ASME and chair of ASME Advanced Energy System Division. He is an Associate Editor of ASME Journal of Energy Resources Technology. He is a member of the Editorial Board of the International Journal of Exergy. He is also a member of the Scientific Council of International Center for Applied Thermodynamics. He has been proposal and scientific paper reviewer for the National Science Foundation, Combustion Science Technology, Combustion Institute, Combustion and Flame, ASME Journal of Energy Resources Technology, ASME Journal of Engineering for Gas Turbine and Power, Biotechnology and American Chemical Society- the Petroleum Research Fund.

Professor Metghalchi’s research is in the area of thermofluids dealing with scientific issues in Combustion, fluid mechanics, thermodynamics, heat transfer and chemical reactions. Professor Metghalchi has supervised 10 Ph.D. theses and 19 M. Sc. theses at Northeastern University. Currently, six graduate students are working under his supervision. Professor Metghalchi has published extensively in education and research in the last twenty five years.

Relevant Publications

[1] M. Metghalchi, J. C. Keck, "Laminar Burning Velocity of Propane-Air Mixtures at High Temperature and Pressure." Combustion and Flame 38: 143-154, 1980.

[2] M. Metghalchi, J. C. Keck, "Burning Velocities of Mixtures of Air with Methanol, Isooctane and Indolence at High Pressure and Temperature." Combustion and Flame 48: 191-210, 1982.

[3] Elia, M., Moore,P., Ulinski, M., and Metghalchi,M., “Laminar Burning Velocity of Methane-Oxygen-Argon (CH_4-O_2-Ar) Mixtures”. Proceedings of the ASME Internal Combustion Engine Division, Columbus Indiana, ICE-Vol. 32-2, 1999.

[4] Elia, M., Ulinski, M. and Metghalchi, M., “Laminar Burning Velocity of Methane-Air-Diluent Mixtures”. ASME Journal of Engineering for Gas Turbines and Power, January 2001, Vol.190-196.

[5] F. Rahim, M. Metghalchi, “Burning Velocity for Spherical Flames in Cylindrical and Spherical Chambers”, Eastern States Combustion Institute, December 2001.

[6] Rahim, F., Metghalchi, M., “Development of Reaction Mechanism and Measurement of Burning Speeds of Methane/Oxidizer/Diluent Mixtures at Low Temperatures and High Pressures”, Western States Combustion Institute, March 2002.

[7] Rahim, F., M. Elia, M. Ulinski and M. Metghalchi, “Burning Velocity Measurements of Methane-Oxygen-Argon Mixtures and Its Application to Extend the Methane-Air Burning Velocity Measurements”, International Journal of Engine Research, Vol. 3, No 2, June 2002.

[8] Parsinejad, F., Matlo, M., Metghalchi, M., “A mathematical Model for Schlieren and Shadowgraph Images of Transient Expanding Spherical Thin Flames”, ASME Journal Engineering for Gas Turbines and Power, 126-2 (2004), 241-247.

[9] Parsinejad, F., Arcari, C., Shirk, E. and Metghalchi, M., “Burning Speed Measurements of JP-8 Air Flames”, Proceeding of ASME International Mechanical Engineering Congress and Exposition, Anaheim, CA, 2004.

Other Publications

[1] R. Law, M. Metghalchi, and J. C. Keck, "Rate-Controlled Constrained Equilibrium calculations of Ignition Delay Times in Hydrogen-Oxygen Mixtures." Twenty-Second Symposium (International) on Combustion, 1988, p. 1705.

[2] P. Bishnu, D. Hamiroune, M. Metghalchi, and J.C. Keck, “Constrained-Equilibrium Calculations for Chemical Systems Subject to Generalized Linear Constraints Using the NASA and STANJAN Equilibrium Programs”. Combustion Theory and Modelling 1 (1997) 295-312.

[3] Hamiroune, D., Bishnu, P., Metghalchi, M. and Keck J.C. “Rate-Controlled Constrained-Equilibrium Method Using Constraint Potentials,” Combustion Theory and Modelling 2 (1998) 81-94

[4} Hui,H., Metghalchi,M., and Keck,J.C. “Estimation of the Thermodynamic Properties of Unbranched Hydrocarbons”. Journal of Energy Resources Technology, March 1999, Vol. 121, 45-50.

[5] Hui, H., Metghalchi, M., and Keck, J. C., “Estimation of the Thermodynamic Properties of Branched Hydrocarbons”. ASME Journal of Energy Resources, September 2000, Vol. 122, 147-152.

B. List of persons, other than those cited in the publication list, who have collaborated on a project or a book, article, report or paper within the last 4 years. Negative reports should be indicated.

Collaborator:	None

C. Names of graduate and Post graduate advisors and advisees.

Graduate Advisor:	James C. Keck
Doctoral Theses Advisees:	Robert Law, Abdolgania Jimoh, Djamel Hamiroune, Partha Bishnu, Hui He, Faranak Rahim, Sergio Ugarte
Post Doctoral Advisees:	Faranak Rahim